# FABRICATION TECHNIQUE OF ACS CAVITY FOR THE JHP

K. Yamasu, T. Iwata and M. Hamaoka
Mitsubishi Heavy Industries, Ltd. Mihara Machinery Works
Itozaki-cho 5007, Mihara-shi, Hiroshima-ken, 729-03, Japan

T. Kageyama, Y. Yamazaki, Y. Morozumi and K. Yoshino
KEK, National Laboratory for High Energy Physics
Oho 1-1, Tsukuba-shi, Ibaragi-ken, 305, Japan

## Abstract

A high-power model of the annular-coupled structure (ACS) was fabricated and tuned to an operating frequency of 1296 MHz for the Japanese Hadron Project (JHP). The nose-cone region is cooled by water channels in the unit in order to make possible the high-duty operation. Some details are described for machining high-Q, ultra-precision cavity segments including coupling slots. Detailed tuning procedures and brazing techniques are also presented.

## Introduction

We have been developing a high-$\beta$ coupled-cavity structure for the Japanese Hadron Project (JHP)[1]. Recent extensive studies on the annular-coupled structure (ACS)[2, 3] have improved its quality factor extremely by understanding its RF characteristics : the quality factor of the ACS is only by 5 or 10 % smaller than that of the side-coupled structure with the same condition. In this way the ACS becomes one of the most attractive candidates for the JHP linac, owing to the high stability and ease of fabrication inherent in the axially symmetric structure of the ACS. Thus, we have fabricated a high-power model of 1296-MHz ACS comprising two accelerator tanks (each 0.5 m long with a diameter of 0.4 m) and a bridge coupler connecting the two tanks shown in Fig. 1. Each tank is a five-cell ACS cavity. Although some techniques developed for the side-coupled structure were effectively applied to the ACS, considerable development was necessary in order to establish economical and efficient fabrication procedure owing to the difference in structure.

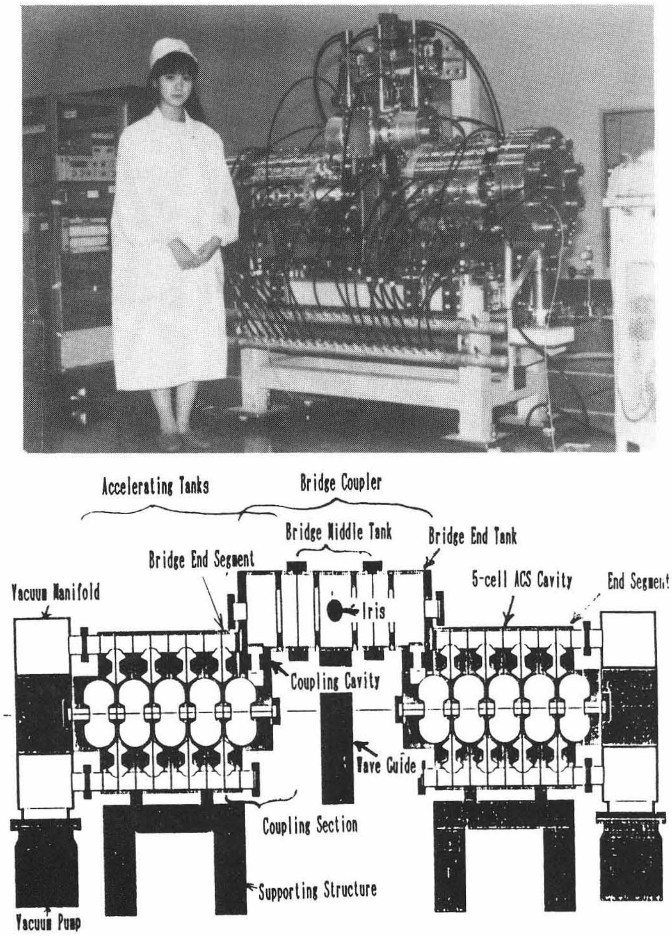

Fig. 1 Annular coupled structure

## Design, Fabrication, and Tuning

### Design

Both a half-accelerating cell and half-coupling cell are formed by machining an oxygen-free copper (OFC) block (Fig.2). The block will be referred to as a half-cell unit in this paper. Water-cooling channels and vacuum-pumping channels are also machined into the half-cell unit in order to minimize the number of brazing processes.

A water-cooling system (5ℓ/min./cell) removes the heat of 1 kW/cell, controlling the average cavity temperature within ± 0.4 ℃. The parallel-path channels are carefully designed in order to minimize the pressure drop and the number of tube fittings, maintaining vacuum tightness and cavity shape.

For the high-duty operation of the JHP linac it is inevitable to cool the nose-cone by conducting cooling water to the nose-cone region. Then, we must drill the water-cooling channels in the wall between the accelerating cell and the coupling cell, requiring some thickness of the wall. However, as the wall becomes thicker, the RF coupling between the accelerating and coupling cell decreases. In order to compensate the decrease of the coupling, we taper-bored the edges of the coupling arc from the coupling-cell side.

## Machining

At first, an OFC ingot is forged into the required half-cell profile. The forged block is then rough-machined ; one side into an accelerating half-cell, while the other into a coupling half-cell, incorporating vacuum-pumping channels. The block, thus rough-machined, is annealed in order to remove the residual stresses which would otherwise be released during finish-machining. This process is important for obtaining the accurate finish-machining. The annealed block is then finish-machined, including the water-cooling channels in both sides, four coupling slots and dimpling holes. The internal surface and the brazing surface are finished with an ultra-precision numerically controlled turning machine (see Fig.2).

Since annealed OFC copper blocks are extremely soft and easily deformed, special care is necessary for accurate finish-machining. First, we require very hard cutting tool : we use natural diamond bites for the finish-machining. Second, we developed a special fixture tool for machining in order to prevent cells from being deformed when clamped. We could machine profiles with a surface roughness of 0.1 to 0.2$\mu$m $R_{max}$ (peak to peak) and dimensional tolerances of $\pm 5\mu$m. (Plane surface to brazed requires flatness less than 10 $\mu$m after pre-braze tuning.) Quality of the surface finish can be evaluated by measuring the quality factor of a cavity. The measured Q-valve was 96 % of the thoeretical value, indicating that the present surface finish was sufficiently good. Here, a single cell was used without coupling slots for comparison with the calculated value.

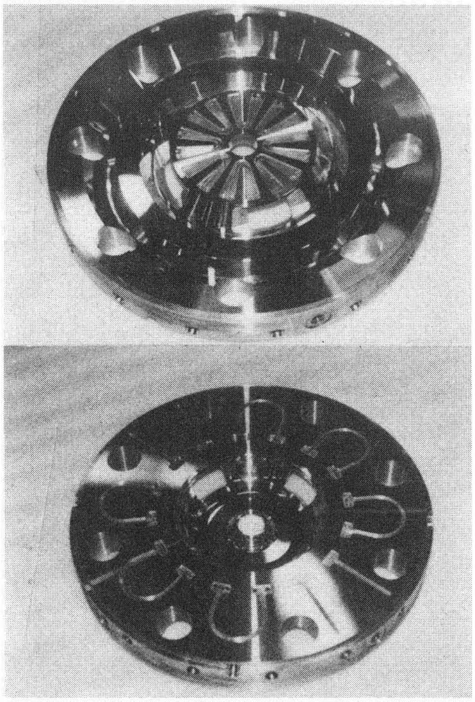

Fig. 2 ACS half-cell showing both sides of the final machined cavity.

## Pre-braze tuning

Before the brazing process, all cavities are machined by using a ultra-precision lathe, until their resonant frequencies are tuned within 100 kHz of the designed value. If the measured frequency of a half-accelerating cell is lower than designed, the nose contour is machined. If higher, the ridge circumferentially prepared in the inner surface of a cavity is machined. Similarly, the coupling half-cells are tuned by removing material from the cell-center gap.

## Brazing

The half-cell units are stacked and brazed in a vacuum furnace as shown in Fig.4. The brazing procedure is schematically shown in Fig. 3. It is seen that the assembling process is divided into three steps. Each brazing step is followed by the check of brazing-joint quality using helium-leak detector.

It is important to optimize the brazing condition, since the braze-joint quality regarding the vacuum tightness is dependent upon the brazing condition. In order to minimize the running-off of the filler metal on the interior surface of a cavity or to the inside of water-cooling channels, the joint clearance should be kept as small and as uniform as possible. Also, it is important to prevent the parts from being overheated and to keep the brazing time as short as possible.

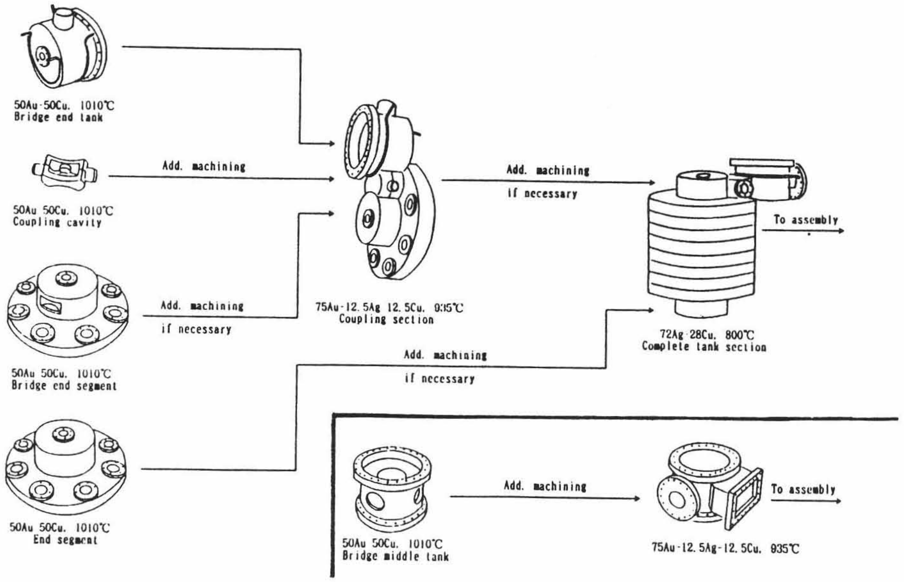

Fig. 3 Brazing assembly steps

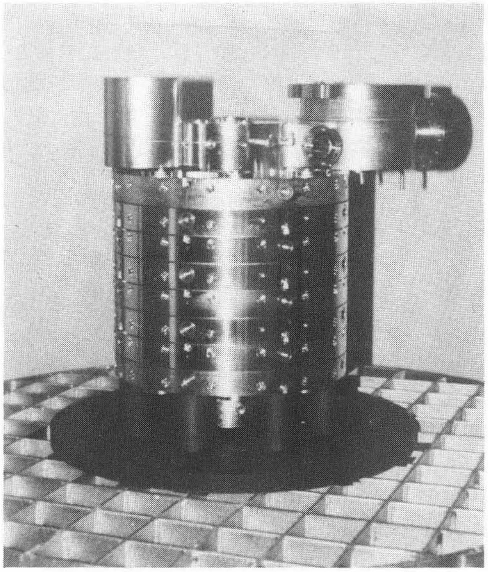

Fig. 4 ACS stack arranged for the brazing process

## Final tuning

After the final brazing, the frequencies of accelerating and coupling cells are measured. If necessary, it is possible to tune either of cells by dimpling the outer cavity wall ; the thin copper wall at the bottom of a hole is pushed inwards to a depth near the interior surface of the cavity.

The iris size of the bridge coupler determines the waveguide coupling coefficient to the accelerator structure. The iris size is adjusted to obtain the good agreement between the measured and designed coupling coefficients.

## Conclusions

A hot model of the ACS has been successfully fabricated for the first time. During the course of development, we have obtained many reliable production techniques which will be also useful for fabricating other types of structure.

In order to save the time of tuning procedure, we must develop appropriate tuning fixtures, with which the RF measurement of half-cell units is possible on a machning fixture.

## References

1. Y. Yamazaki and M. Kihara, "Development of the High-Intensity Proton Linac for the Japanese Hadron Project", this conference.
2. T. Kageyama et al., Part. Accel. 32, 33 (1990)
3. T. Kageyama et al., "A High Power Model of the ACS Cavity." this conference.